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Richard A. Roline

James J. Sartoris

U.S. Bureau of Reclamation

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Richard A. Roline
James J. Sartoris
U.S. Bureau of Reclamation, P.O. Box 25007, Denver, Colorado 80225

ABSTRACT

Las Vegas Wash, a natural wash east of Las Vegas, Nevada, carries stormwater, groundwater drainage, and sewage effluent from two sewage treatment plants to Lake Mead. Over 80 percent of the normal discharge of approximately 3.4 m^3/s (120 ft^3/s) consists of effluent from the City of Las Vegas and Clark County sewage treatment plants. Beginning in the 1950s, a large wetland area developed along the wash that supported waterfowl populations and contributed to some water quality transformations. Heavy rains and subsequent flooding in the area in 1983 and 1984 resulted in erosion and channelization that greatly reduced the wetland area within Las Vegas Wash. The reduction in wetland area shortened water travel time in the wash and affected water quality. The primary impacts on the water entering Lake Mead have been an increase in temperature, a decrease in dissolved oxygen concentration, and an increase in ammonia levels. Other physical–chemical parameters and changes in nutrient transformations are also discussed.

Introduction

Las Vegas Wash is a natural wash located east of the City of Las Vegas, Nevada (Fig. 1). It drains the entire Las Vegas Valley, which is primarily a desert environment. The Wash channels area storm runoff, groundwater drainage, and secondary and tertiary sewage effluent from the City of Las Vegas sewage treatment plant (STP) and the Clark County Advanced Wastewater Treatment (AWT) Plant into Las Vegas Bay of Lake Mead. In response to rapid population growth in the Las Vegas area since the 1950s, the wash became a perennial stream with a normal discharge today of 3.4 m^3/s (120 ft^3/s), consisting of about 80 percent sewage effluent and 20 percent primarily industrial cooling water and regional groundwater drainage.

Las Vegas Wash includes an area of channelled inflows, marsh, and an eroded stream section that carries water to Las Vegas Bay of Lake Mead. The marsh developed over the years in response to increasing water availability. It became an important habitat for local waterfowl, and benefited the sewage treatment plants by helping them meet water quality criteria for discharges into Lake Mead.

In 1983 and 1984, the morphometry of the wash changed drastically. Severe flooding and erosion moved the lower channel headcut further upstream, creating a more confined channel and reducing the marsh cattail area to about 40 percent of its former size (U.S. Bur. Reclam. 1987). Dye studies showed that the reduction in marsh area decreased the travel time of water through the entire wash from about 18 hours (Brown and Caldwell, 1982) to less than 6 hours (Sartoris and Roline, 1987). Residence time within the marsh area was reduced from 15 hours to about 2.5 hours.

The effects of these changes in the morphometry of Las Vegas Wash on water quality entering Lake Mead were evaluated by comparing the results of three water quality studies. The first study was performed by Frank Morris from July 1979 through

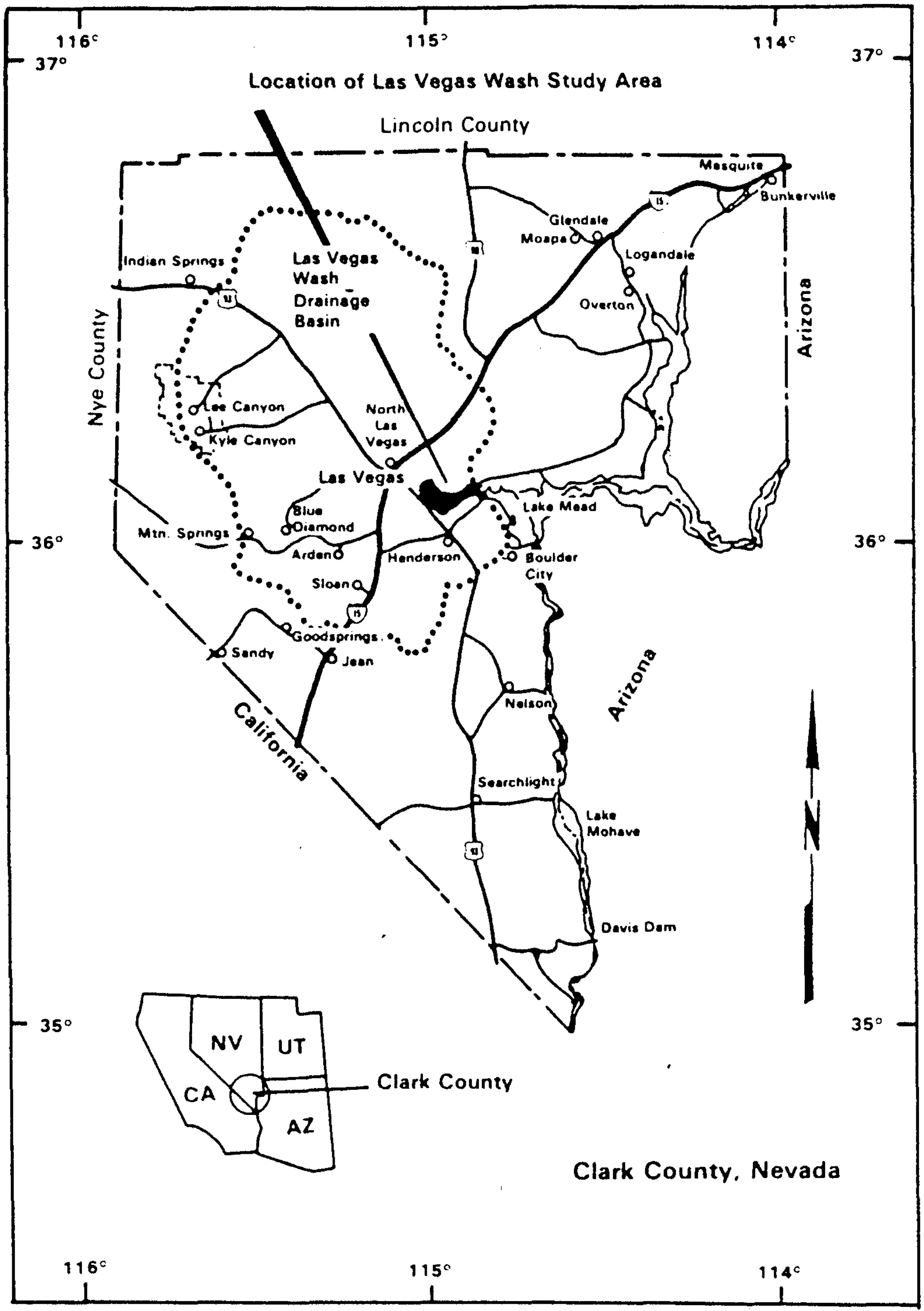

Figure 1.–Location map and study area, Clark County, Nevada (Morris, 1983).

December 1980, as part of a larger water quality standards study done by Brown and Caldwell, Consulting Engineers (Brown and Caldwell, 1982; Morris, 1983). In 1983, the authors conducted a brief, intensive study, consisting of four surveys, that updated the results of Morris' study to include the effects of the Clark County AWT Plant on phosphorus concentrations in Las Vegas Wash (Roline and Sartoris, 1984). This plant had begun operation in 1982. Together these two studies established the pre-flood water quality conditions in the wash. Post-flood conditions were the subject of the present study, which was carried out from December 1985 through January 1987 (Sartoris and Roline, 1987).

Study Area

The study area (Fig. 2) extends from the east side of the City of Las Vegas to Las Vegas Bay on the west side of Lake Mead. In this report, 3 of the 17 stations originally sampled will be considered in relation to nitrogen and phosphorus compound concentrations. The morphometry and the composition of the vegetation within the marsh area are, and have been, continually changing to some extent; however, during the flooding in 1983 and again in 1984, large portions of the existing marsh were eroded, leaving a defined channel. An evaluation of vegetation in Las Vegas Wash using remote sensing (U.S. Bur. Reclam. 1987) concluded that the most noteworthy change recently has been the reduction of marsh habitat. This was largely a decline in cattails (*Typha domingensis*); however, reeds (*Phragmites communis*) were also affected. Changes were most evident in the lower marsh area near Pabco Road (Fig. 2). Scouring and draining drastically changed the extent of the two vegetation communities in this area. Within the main marsh area, cattail coverage was reduced by approximately 70 ha (174 acres) between 1982 and 1986, from a coverage of 122 ha (302 acres) in 1982. In the same period reed coverage increased from 59 to 70 ha (147 to 174 acres).

Methods and Materials

Methods used in all three studies were comparable. In the most recent study, monthly surveys were performed from December 1985 through January 1987. During each survey, in-situ physical–chemical parameters were measured, and water samples were collected to determine concentrations of nitrogen and phosphorus compounds. Field measurements were done with a Hydrolab Surveyor

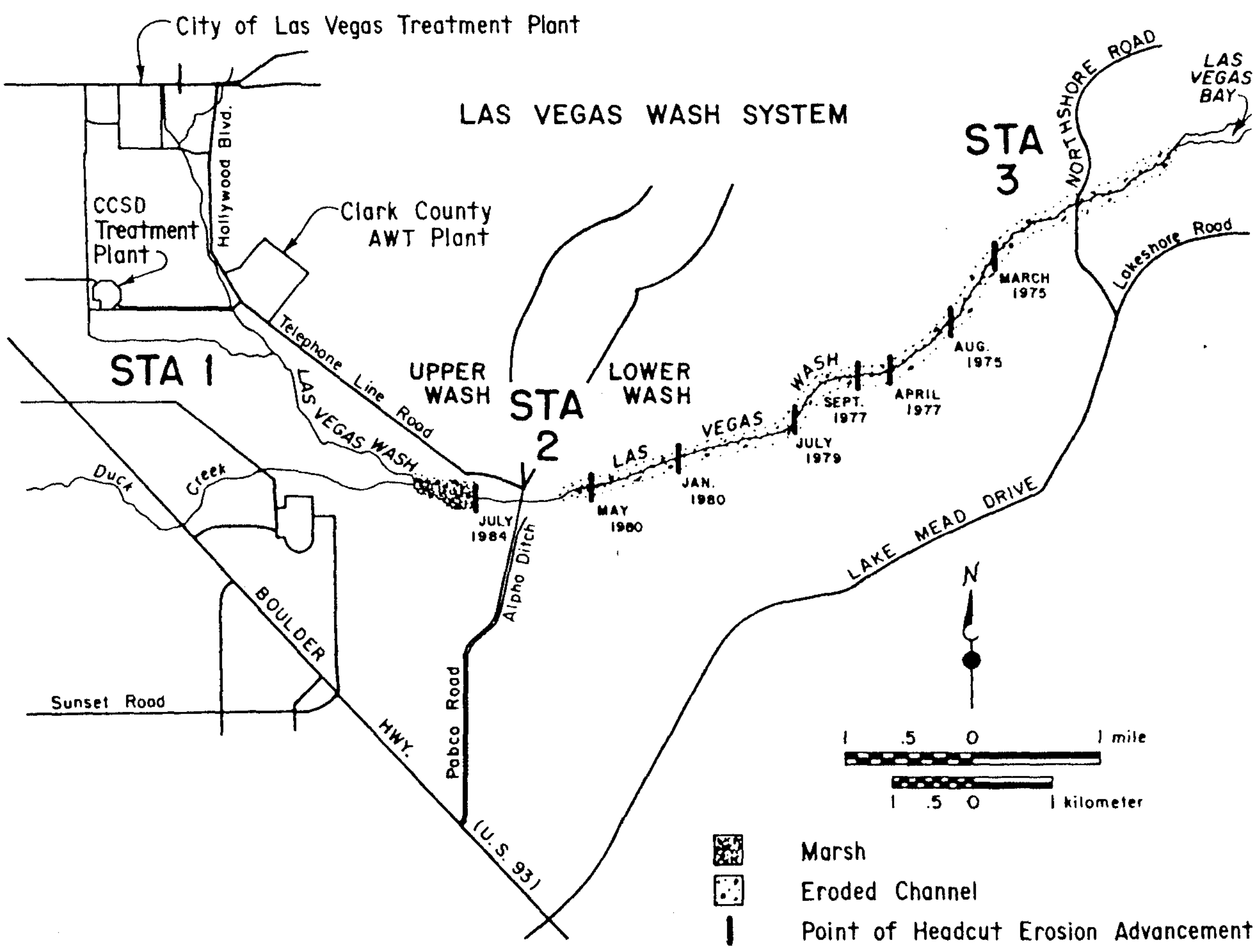

Figure 2.—Sampling site locations and headcut erosion proximity (adapted from Morris, 1983).

II (Austin, Texas) multiparameter probe. Water temperatures, pH, dissolved oxygen concentrations, and electrical conductivities were measured. The instrument was calibrated at the field site using a barometer and standard laboratory solutions. Discharge information was obtained from the City of Las Vegas STP, Clark County AWT Plant, and the U.S. Geological Survey (USGS).

A 500 ml water sample was collected and frozen for the analyses of nitrogen and phosphorus compounds. A 40 ml subsample was filtered through a 0.45 μm disposable filter and frozen to determine the dissolved orthophosphate concentration. All samples were analyzed according to methods described in Chapter 5, "Chemical and Physical Quality of Water and Sediments," of the *National Handbook of Recommended Methods for Water-Data Aquisition* (U.S. Geolog. Surv. 1977).

Results and Discussion

Since the early 1980s, two important changes have taken place in Las Vegas Wash that have affected the water quality. Water quality in the wash both before and after these changes is compared in Tables 1 and 2.

The first of these changes, the construction and operation of the Clark County AWT Plant in 1982, reduced total phosphorus within Las Vegas Wash at the inflow to Lake Mead (Station 3) to less than 0.5 mg/l (Table 2). Phosphorus removal was accomplished with the use of lime, which raised the pH at Station 1 to about 8.1 from an earlier level of 7.2 (Table 1). Since the AWT Plant began operation, phosphorus levels within the wash have not changed significantly, as documented by Roline and Sartoris (1984) in the interim study.

Table 1.—Comparison of an annual cycle of physical-chemical data between the 1979-1980 and 1986-87 field studies.

STATION	PARAMETER	STATISTIC	(MORRIS, 1983) 1979-80	(SARTORIS AND ROLINE, 1987) 1986-87
1	Temperature (°C)	n =	30	13
		$\bar{x}$ =	21.1	20.5
		Range =	13.5-27.5	14.9-27.0
	pH	n =	28	13
		$\bar{x}$ =	7.2	8.1
		Range =	6.7-7.7	7.4-8.4
	Dissolved oxygen (mg/l)	n =	28	13
		$\bar{x}$ =	5.0	6.4
		Range =	1.4-7.9	3.9-7.7
	Electrical conductance (μS/cm)	n =	30	13
		$\bar{x}$ =	2490	1840
		Range =	1020-3450	1650-2080
2	Temperature (°C)	n =	30	13
		$\bar{x}$ =	18.0	20.0
		Range =	12.5-28.0	13.6-27.3
	pH	n =	28	13
		$\bar{x}$ =	7.4	7.5
		Range =	6.7-7.8	7.3-7.6
	Dissolved oxygen (mg/l)	n =	28	13
		$\bar{x}$ =	0.6	4.9
		Range =	0.0-3.0	3.8-5.8
	Electrical conductance (μS/cm)	n =	30	13
		$\bar{x}$ =	2070	2260
		Range =	860-2400	1970-2970
3	Temperature (°C)	n =	30	13
		$\bar{x}$ =	17.4	21.1
		Range =	11.0-24.8	13.5-29.0
	pH	n =	28	13
		$\bar{x}$ =	7.7	7.8
		Range =	6.2-8.7	7.5-8.0
	Dissolved oxygen (mg/l)	n =	28	13
		$\bar{x}$ =	8.1	7.0
		Range =	4.8-10.9	5.7-9.0
	Electrical conductance (μS/cm)	n =	30	13
		$\bar{x}$ =	3230	2610
		Range =	2900-4300	2330-3270

Table 2.—Comparison of nitrogen and phosphorus concentrations between the 1979-80 and 1986-87 field studies.

STATION	PARAMETER	STATISTIC	(MORRIS, 1983) 1979-80	(SARTORIS AND ROLINE, 1987)
1	Total P(mg/l)	n =	36	14
		x̄ =	3.46	0.611
		s =	0.97	0.106
		Range =	1.60-7.10	0.375-0.765
	Dissolved Ortho P (PO_4-P) (mg/l)	n =	32	14
		x̄ =	2.04	0.431
		s =	0.49	0.100
		Range =	1.00-3.00	0.239-0.569
	Nitrate (NO_3-N) (mg/l)	n =	36	14
		x̄ =	1.14	1.39
		s =	2.20	0.44
		Range =	0.06-10.0	0.666-2.01
	Total Ammonia ($NH_3 + HN_4^+$-N) (mg/l)	n =	36	14
		x̄ =	14.3	14.6
		s =	2.6	1.5
		Range =	9.80-19.0	12.0-16.8
	Un-ionized Ammonia* (NH_3-N) (%)	n =	28	13
		x̄ =	0.53	4.0
	Total Kjeldahl Nitrogen (TKN-N) (mg/l)	n =	36	14
		x̄ =	18.4	15.7
		s =	2.9	1.7
		Range =	13.0-24.0	13.6-18.6
2	Total P (mg/l)	n =	20	14
		x̄ =	2.71	0.568
		s =	0.61	0.081
		Range =	1.20-4.30	0.439-0.703
	Dissolved Ortho P (PO_4-P) (mg/l)	n =	20	14
		x̄ =	2.61	0.490
		s =	0.55	0.096
		Range =	1.50-4.20	0.358-0.621
	Nitrate (NO_3-N) (mg/l)	n =	20	14
		x̄ =	1.09	0.417
		s =	3.05	0.543
		Range =	0.010-10.0	0.015-1.55
	Total Ammonia ($NH_3 + NH_4^+$-N) (mg/l)	n =	20	14
		x̄ =	14.9	13.9
		s =	2.7	1.2
		Range =	6.80-17.0	11.2-15.6
	Un-ionized Ammonia* (NH_3-N) (%)	n =	28	13
		x̄ =	0.67	1.0
	Total Kjeldahl Nitrogen (TKN-N) (mg/l)	n =	20	14
		x̄ =	16.7	15.0
		s =	2.6	1.5
		Range =	7.50-19.0	12.4-17.7
3	Total P (mg/l)	n =	36	14
		x̄ =	2.67	0.479
		s =	2.41	0.083
		Range =	1.20-15.0	0.353-0.603
	Dissolved Ortho P (PO_4-P) (mg/l)	n =	33	14
		x̄ =	1.58	0.397
		s =	0.45	0.081
		Range =	0.500-2.60	0.277-0.519
	Nitrate (NO_3-N) (mg/l)	n =	36	14
		x̄ =	2.87	2.03
		s =	2.84	0.86
		Range =	0.710-12.0	0.978-3.73
	Total Ammonia ($NH_3 + NH_4^+$-N) (mg/l)	n =	36	14
		x̄ =	7.96	9.89
		s =	1.75	1.53
		Range =	4.10-12.0	7.72-12.2
	Un-ionized Ammonia* (NH_3-N) (%)	n =	28	13
		x̄ =	1.3	2.2
	Total Kjeldahl Nitrogen (TKN-N) (mg/l)	n =	36	14
		x̄ =	9.72	11.1
		s =	1.94	2.0
		Range =	6.70-15.0	7.76-15.2

* Percent un-ionized ammonia is based on the mean temperature and pH values at an estimated total dissolved solids concentration of 2000 mg/l.

The second important change was the flooding in 1983 and 1984, which reduced the cattail marsh area by about 60 percent. It was hypothesized that the reduction would have a noticeable impact on various water quality parameters, particularly on nitrogen compounds, even though in the previous study (Roline and Sartoris, 1984) it appeared that nutrient uptake by vegetation directly from the water was negligible. Two factors precluded significant vegetative removal of nitrogen and phosphorus from the flow of Las Vegas Wash: dominant vegetation type and flow retention time. The dominant vegetation type in the Las Vegas Wash wetlands was cattail (*Typha domingensis*), a rooted emergent aquatic macrophyte. The common reed (*Phragmites communis*), which is a marginal rooted hydrophyte, was the second major plant in the marsh community. Both of these plants depend primarily on their roots to take up nutrients, unlike submersed or floating aquatic macrophytes (Barten, 1983; Reddy, 1983; Chan et al. 1982). The second factor precluding significant vegetative uptake from the flow was that even the former 15-hour average retention time in the wetlands portion of the wash (Morris, 1983) was much shorter than the minimum four to five day retention times found necessary in most wetlands nutrient removal studies (Barten, 1983; Reddy, 1983; Spangler et al. 1976). The reduction in marsh area and resulting decrease in residence times, however, resulted in some changes in both physical and chemical properties of the water within the wash.

Because mean discharge increased from about 2.7 m^3/s (95 ft^3/s) in 1979-80 to 3.4 m^3/s (120 ft^3/s) in 1986-87, and wetland residence time was reduced, the water reaching Station 3 (Northshore Road) averages over 3°C warmer than it has in the past. This, of course, varies from day to day and season to season, but less cooling of the wastewater within the marsh area seems evident. The dissolved oxygen at Station 2 is much greater today than it was in the study by Morris (1983), when the sampling station was located within the cattail marsh. Since then, a large marsh area has been lost and aeration occurs quickly in the channelized turbulent flow. Electrical conductance in the wash during the 1979-80 study was generally higher than at present. The decline probably was due to dilution from higher sewage treatment plant discharges and possible reductions in regional groundwater salinity and/or discharge.

In general, the present concentrations of nitrogen appear to be similar to those measured before the recent period of marsh erosion began; however, the concentrations of certain nitrogen compounds appear to have been affected somewhat by the reduction in marsh area within Las Vegas Wash. The mean total ammonia concentrations during the 1979-80 study decreased from 14.3 mg/L to 7.96 mg/L between Stations 1 and 3, a reduction of 44 percent. During the 1983 study the levels decreased 64 percent, from 14.6 mg/L to 5.20 mg/L. Following the marsh erosion, weekly data from the Clark County Sanitation District monitoring program for 1984, 1985, and 1986 showed that inflow levels of 13.2, 15.5, and 17.7 mg/L were reduced to 7.1 (46 percent), 11.2 (28 percent), and 13.3 (25 percent) mg/L by Station 3. The mean reduction in total ammonia concentration during the 1986-87 study was 32 percent, from 14.6 mg/L to 9.89 mg/L. It seems that the actual reduction of total ammonia concentrations within Las Vegas Wash has declined from 6 mg/L or greater to about 4 mg/L following marsh erosion. This is not particularly significant in itself, but combined with the general increase in temperature and pH at Station 3, it may be important with regard to the un-ionized fraction of the total ammonia, which is toxic to fish. The percentage of the total ammonia in the un-ionized form at Station 3 rose from an average of 1.3 percent during the 1979-80 study to 2.2 percent during the 1986-87 study. This percentage depends upon the pH, temperature, and total dissolved solids concentration of the aqueous ammonia solution. The percentage is directly proportional to pH and temperature, and inversely proportional to total dissolved solids, which is reflected by the electrical conductance (Skarheim, 1973). Even though the mean total ammonia concentrations have apparently increased about 24 percent between the two study periods, the total ammonia load entering Lake Mead by Las Vegas Wash has increased from 1854 kg/day to 2906 kg/day for an increase of 57 percent.

A criterion of 0.016 mg/L NH_3-N (un-ionized ammonia expressed as elemental N) has been established by the U.S. Environmental Protection Agency (1976) for the protection of freshwater aquatic life. Concentrations of NH_3-N throughout Las Vegas Wash consistently exceeded this criterion during the present study. Brown and Caldwell (1982) recommended an un-ionized ammonia criterion of 0.02 mg/L NH_3-N in Las Vegas Bay for the protection of the fishery. As shown in an ongoing monitoring program by the University of Nevada, Las Vegas, this level is sometimes approached and exceeded, at least in the wastewater plume itself and in inner Las Vegas Bay; however, toxicity resulting from ammonia would not likely occur because of the large dilution factor and the fish's capability for avoidance.

A more serious consequence of the increased ammonia levels, both total and un-ionized, and the higher temperature of the Las Vegas Wash water as it enters Lake Mead at present, is the potential for increasing algal production to nuisance levels because of the near-surface, nutrient-rich inflow. An increase in algal production could affect water quality and recreational activities within the immediate area.

Conclusions

Flash floods during the summers of 1983 and 1984 reduced the area of the Las Vegas Wash wetlands by about 60 percent. Travel time through the wash from the confluence of the sewage treatment plant discharges to Lake Mead was also reduced from an average of approximately 18 hours in 1980 to less than 6 hours in 1985. These changes in morphometry and travel time have affected the quality of water entering Lake Mead. The major effects may be summarized as follows:

■ **Water temperature:** Formerly, retention in the cattail marsh cooled the water to some extent; now, the water is cooled less as it travels from the sewage treatment plant to the lake. Warmer temperatures at Station 3 increase the percentage of ammonia in the un-ionized form and make surface overflows in Las Vegas Bay more likely.

■ **pH:** Lime treatment for phosphorus removal at the AWT plant raised the pH significantly at Station 1, resulting in slightly higher pH at both downstream stations.

■ **Dissolved oxygen:** Dissolved oxygen depletion in the marsh (Station 2) is now much reduced, but concentrations at Station 3 are less now because of higher water temperatures and increased ammonia oxygen demand.

■ **Phosphorus:** The dramatic reduction in the concentration of this nutrient is due to the AWT plant which began operating in 1982, rather than to any change in the wash itself.

■ **Nitrogen:** Total nitrogen concentrations in the upper wash (Stations 1 and 2) are lower today than in 1979-80, largely because of a decrease in the average concentration of organic nitrogen of about 3 mg/L; however, the loss of marsh and the decreased travel time through the wash have reduced the rate of nitrification to the point where total ammonia concentrations at Northshore Road (Station 3) now average nearly 2 mg/L more than in 1979-80. Given the higher pH that now prevails in Las Vegas Wash below the AWT plant, and the warmer temperatures in the lower wash, this increase in total ammonia concentration translates into a higher percentage of un-ionized ammonia at all stations.

Finally, attention should be given to what might be done to improve the capacity of the Las Vegas Wash wetlands to remove nutrients, especially ammonia, from the sewage effluents before they reach Las Vegas Bay. Recently, Gersberg et al. (1986) reported an average reduction in ammonia concentration of about 28 percent (from 24.7 mg/L to 17.7 mg/L) in primary-treated sewage effluent in cattail beds in southern California. The basis of this removal was not uptake by the plants, but rather sequential nitrification and dentrification in the aerobic root zones of the cattails and the anaerobic sediments, respectively.

Using criteria from this study (Gersberg et al. 1986), a mean depth of 0.76 m (2.5 ft), a retention time of six days, and assuming a flow of 3.4 m^3/s (120 ft^3/s) of secondary-treated sewage, a conservative estimate of the minimum required cattail wetland area for effective ammonia removal in Las Vegas Wash is about 231 ha (571 acres). The actual cattail marsh area in Las Vegas Wash in 1986 was estimated at approximately 52 ha (128 acres), a reduction from about 122 ha (302 acres) in 1982 (U.S. Bur. Reclam. 1987). Mean depths in these wetlands are unknown, but water residence times averaged 15 hours in 1982 and approximately 2.5 hours in 1986.

Morris (1983) has presented several ideas for structures that might be used to upgrade the existing Las Vegas Wash wetlands to a condition more nearly approaching the criteria of Gersberg et al. (1986). These ideas could form the basis for a study of the feasibility of establishing a more effective wetlands treatment system between the sewage treatment plants and Lake Mead.

References

Barten, J. 1983. Nutrient removal from urban stormwater wetland filtration. N. Am. Lake Manage. Soc. Lake Line 3(3): 6-11.

Brown and Caldwell. 1982. Draft Report - Water Quality Standards Study. Sacramento, CA.

Chan, E., P.E. Bursztyasky, P.E. Hantzsche, and Y.J. Litwin. 1982. The Use of Wetlands for Water Pollution Control. EPA-600/2-82-086. U.S. Environ. Prot. Agency, Cincinnati, OH.

Gersberg, R. M., B. V. Elkins, S. R. Lyon, and C. R. Goldman. 1986. Role of aquatic plants in wastewater treatment by artificial wetlands. Water Res. 20(3): 363-68.

Morris, F. A. 1983. Effects of a desert wetland on water quality of wastewater effluents. Master's Thesis. Univ. Nevada–Las Vegas, NV.

Reddy, K. R. 1983. Fate of nitrogen and phosphorus in a wastewater retention reservoir containing aquatic macrophytes. J. Environ. Qual. 12(1): 137-41.

Roline, R. A. and J. J. Sartoris. 1984. Las Vegas Wash Advanced Water Quality Study. Final Rep. U.S. Bur. Reclam. Denver, CO.

Sartoris, J. J. and R. A. Roline. 1987. Las Vegas Wash Effluent Monitoring Study. Rep. Progr. - 1986. Appl. Sci. Refer. No. 87-2-9. U.S. Bur. Reclam. Denver, CO.

Skarheim, H. P. 1973. Tables of the fraction of ammonia in the undissociated form. SERL Rep. No. 73-5. Univ. California. Berkeley.

Spangler, F. L., W. E. Sloey, and C. W. Fetter. 1976. Wastewater Treatment by Natural and Artificial Marshes. EPA-600/2-76-207. U.S. Environ. Prot. Agency, Ada, OK.

U.S. Bureau of Reclamation. 1987. Las Vegas Wash vegetation study. Denver, CO.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Washington DC.

U.S. Geological Survey. 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Reston, VA.